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Saccharina latissima and *Psammechinus miliaris* on variable salinity grazed infralittoral rock

MarLIN – Marine Life Information Network
Marine Evidence-based Sensitivity Assessment (MarESA) Review

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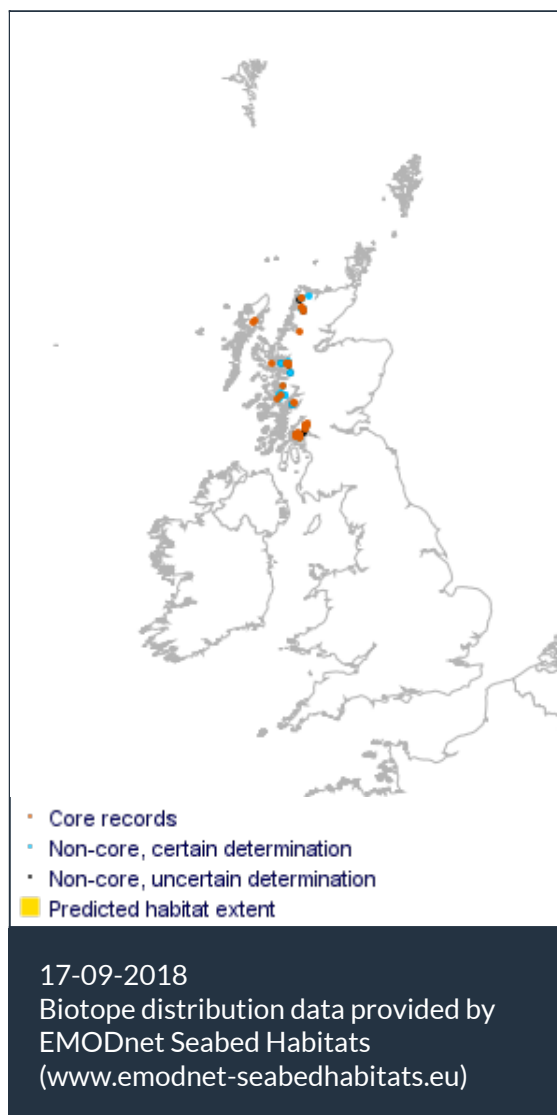
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Laminaria saccharina and *Psammechinus miliaris* on variable salinity grazed infralittoral rock

Photographer: Keith Hiscock

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Researched by Thomas Stamp Refereed by Admin

Summary

UK and Ireland classification

EUNIS 2008	A3.322	<i>Laminaria saccharina</i> and <i>Psammechinus miliaris</i> on variable salinity grazed infralittoral rock
JNCC 2015	IR.LIR.KVS.SlatPsaVS	<i>Saccharina latissima</i> and <i>Psammechinus miliaris</i> on variable salinity grazed infralittoral rock
JNCC 2004	IR.LIR.KVS.LsacPsaVS	<i>Laminaria saccharina</i> and <i>Psammechinus miliaris</i> on variable salinity grazed infralittoral rock
1997 Biotope	IR.SIR.K.LsacRS.Psa	<i>Laminaria saccharina</i> and <i>Psammechinus miliaris</i> on slightly reduced salinity grazed infralittoral rock

Description

Sheltered bedrock, boulders and cobbles, in areas of reduced salinity, with kelp *Saccharina latissima*, and depauperate coralline-encrusted rock supporting few foliose seaweeds but many

grazing urchins *Psammechinus miliaris* and *Echinus esculentus*. The coralline crusts are typically *Lithothamnion glaciale*, while the brown crusts can be *Pseudolithoderma extensum*. Encrusting polychaetes *Spirobranchus* (formerly *Pomatoceros*) *triqueter*, resistant to the grazing, are also present on most of the rock. The grazing fauna are a significant component of this biotope; large numbers of *Psammechinus miliaris* are typically present, although where absent the brittlestar *Ophiothrix fragilis* may occur. Other grazers prevalent on the rock include the chiton *Tonicella marmorea*, the limpet *Tectura testudinalis* and the gastropod *Gibbula cineraria*. A combination of grazing pressure and lowered salinity maintains a low diversity of species in this biotope, with foliose and filamentous seaweeds generally absent or reduced to small tufts by grazing. In stark contrast to the range of seaweeds present in the *Laminaria saccharina* forests (Slat.Ft) the only red seaweed consistently found in this biotope is *Phycodrys rubens*. The range of fauna is similarly low, with a conspicuous absence of hydroids and bryozoans. Bedrock and boulders provide a firm substrate on which ascidians *Ciona intestinalis* and *Ascidia mentula* and the bivalve *Modiolus modiolus* can attach. The crabs *Pagurus bernhardus* and *Carcinus maenas* can usually be found here, though *Necora puber* typically is absent due to the brackish conditions. The starfish *Asterias rubens* along with the whelk *Buccinum undatum* can be present. The substratum on which this biotope occurs varies from bedrock to boulders or cobbles on sediment. The kelp band is relatively narrow and shallow (upper 5 m) compared to Slat.Ft, although the grazed coralline encrusted rock extends deeper. This depth limit becomes shallower towards the heads of the sealochs (taken from Connor *et al.*, 2004).

↓ Depth range

0-5 m, 5-10 m

🏛️ Additional information

-

✓ Listed By

- none -

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS & IR.LIR.KVS.SlatPsaVS are within the “Kelp in Variable or Reduced Salinity” habitat complex (IR.LIR.KVS), which are predominantly shallow low energy biotopes found in areas of low or reduced salinity typically in Scotland but also in other sheltered locations around the British Isles e.g. harbours. IR.LIR.KVS.Cod is characterized by dense stands of *Codium* spp., silt tolerant red seaweeds and sparse *Saccharina latissima* (syn. *Laminaria saccharina*). IR.LIR.KVS.SlatPsaVS is characterized by *Saccharina latissima* but intense *Psammechinus miliaris* grazing combined with low salinity maintains low biodiversity, resulting in an understory community of depauperate coralline-encrusted rock with predominantly grazing resistant or mobile fauna e.g. *Pomotoceros* spp. IR.LIR.KVS.SlatPhyVS is characterized by *Saccharina latissima* with dense stands of silted filamentous green seaweeds and red seaweeds; *Phyllophora crispa*, *Phyllophora pseudoceranoides* and *Phycodrys rubens*.

In undertaking this assessment of sensitivity, an account is taken of knowledge of the biology of all characterizing species in the biotope. For this sensitivity assessment *Codium* spp., *Saccharina latissima* represent the dominant characterizing algae, and *Psammechinus miliaris* represent urchin grazers are the primary foci of research, it is recognized that the understory red seaweed communities of IR.LIR.KVS.Cod and IR.LIR.KVS.SlatPhyVS also define these biotopes. Examples of important species groups are mentioned where appropriate.

The biotopes IR.LIR.KVS biotope complex is distinguished by the relative abundance of *Saccharina latissima*, and *Codium* sp, the diversity of red and brown algae that ranges between low salinity or scour tolerant species, and presence or absence of grazers. The sensitivity of the dominant kelp and red algae are probably consistent for most of the pressures assessed. Therefore, except where indicated, all assessments are considered to apply to all the biotopes within the biotope complex.

Resilience and recovery rates of habitat

There are four species of *Codium* spp. and two sub-species in the UK; *Codium fragile* subsp. *atlanticum*, *Codium fragile* subsp. *tomentosoides*, *Codium bursa*, *Codium tomentosum* and *Codium vermilaria* (Silva, 1955; Bunker et al., 2012). IR.LIR.KVS.Cod does not specifically refer to 1 (sub) species as characteristic, therefore, evidence used within this assessment has been sourced from literature cover all 6 species and subspecies. *Codium* spp. has a perennial life strategy (Bulleri & Airoidi, 2005). Viable zoospores can be produced in the first year of growth from June to autumn (Churchill & Moeller, 1972), spores then germinate and germlings persist through winter undergoing rapid thalli growth when water temperature increases the following spring/summer (Haniask, 1979; Bulleri & Airoidi, 2005). In successive years, the thalli can fragment during winter reducing individuals to a holdfast which may then persist throughout the winter (Fralick & Methieson, 1972), in early spring (April-May) a new frond will develop from the holdfast (Trowbridge, 1995, 1996). *Codium fragile* gametes can settle and germinate on a variety of substrata including rock fractions, as well as shellfish, coralline algae, serpulid casts and solitary ascidians (Bulleri & Airoidi, 2005). Recruitment is, however, strongly influenced by temperature (see below), salinity (see below), wave exposure and the availability of bare space at the time of gamete release (Trowbridge, 1995, 1998, 1999; Bégin & Scheibling, 2003). Fralick & Methieson (1972) suggested cold temperatures caused *Codium* spp. thalli to fragment and that fragmented sections of *Codium* were then capable of reattachment to hard substrata by means of colourless filaments which grow from the point of fragmentation. In most cases it took several weeks for re-

attachment to occur but in summer fragments could re-attach within 3-6 days.

Saccharina lattisma is a perennial kelp characteristic of wave sheltered sites of the North East Atlantic, distributed from northern Portugal to Spitzbergen, Svalbard (Birkett *et al.*, 1998; Connor *et al.*, 2004; Bekby & Moy, 2011; Moy & Christie, 2012). *Saccharina lattisma* is capable of reaching maturity within 15-20 months (Sjötun, 1993) and has a life expectancy of 2-4 years (Parke, 1948). Maximum growth has been recorded in late winter early spring, in late summer and autumn growth rates slow (Parke, 1948; Lüning, 1979; Birkett *et al.*, 1998). The overall length of the sporophyte may not change during the growth season due to the marginal (distal) erosion of the blade, but extension growth of the blade has been measured at 1.1 cm/day, with total length addition of over 2.25m of tissue per year (Birkett *et al.*, 1998). *Saccharina latissima* has a heteromorphic life strategy. Large numbers of zoospores are released from sori located centrally on the blade between autumn and winter. Zoospores settle onto rock substrata and develop into dioecious gametophytes (Kain, 1979) which, following fertilization, germinate into juvenile sporophytes from winter-spring. Kelp zoospores are expected to have a large dispersal range, however, zoospore density and the rate of successful fertilization decreases exponentially with distance from the parental source (Fredriksen *et al.*, 1995). Hence, recruitment following disturbance can be influenced by the proximity of mature kelp beds producing viable zoospores to the disturbed area (Kain, 1979; Fredriksen *et al.*, 1995).

A large pressure for *Laminaria hyperborea* biotopes (e.g. IR.HIR.KFaR.LhypR) is urchin grazing pressure, particularly from the species *Echinus esculentus*, *Paracentrotus lividus* and *Strongylocentrotus droebachiensis*. Multiple authors (Steneck *et al.*, 2002; Steneck *et al.*, 2004; Rinde & Sjötun, 2005; Norderhaug & Christie, 2009; Smale *et al.*, 2013) have reported dense aggregations of sea urchins to be a principal threat to *Laminaria hyperborea* biotopes of the North Atlantic. Intense urchin grazing creates expansive areas known as “urchin barrens”, in which a shift can occur from *Laminaria hyperborea* dominated biotopes to those characterized by coralline encrusting algae, with a resultant reduction in biodiversity (Leinaas & Christie, 1996; Steneck *et al.*, 2002, Norderhaug & Christie, 2009). Continued intensive urchin grazing pressure on *Laminaria hyperborea* biotopes can inhibit the *Laminaria hyperborea* recruitment (Sjötun *et al.*, 2006) and cause urchin barrens to persist for decades (Christie *et al.*, 1998; Steneck *et al.*, 2004; Rinde & Sjötun, 2005). A kelp recolonization experiment conducted by Leinaas & Christie (1996) removed *Strongylocentrotus droebachiensis* from “urchin barrens” and observed a succession effect. It was observed that the substratum was initially colonized by filamentous macroalgae and within 2 weeks *Saccharina latissima* colonized and persisted for 2 years. However after 2-4 years *Laminaria hyperborea* dominated the community. Despite *Laminaria hyperborea*’s eventual dominance within the community Leinaas & Christie (1996) demonstrated that *Saccharina latissima* can colonize cleared areas rapidly.

In 2002 a 50.7-83 % decline of *Saccharina latissima* was discovered in the Skaggerak region, South Norway (Moy *et al.*, 2006; Moy & Christie, 2012). Survey results indicated a sustained shift from *Saccharina latissima* communities to those of ephemeral filamentous algal communities. The reason for the community shift was unknown, but low water movement in wave and tidally sheltered areas combined with the impacts of dense human populations e.g. increased land run-off, was suggested to be responsible for the dominance of ephemeral turf macro-algae. Multiple stressors such as eutrophication, increasing regional temperature, increased siltation and overfishing may also be acting synergistically to cause the observed habitat shift.

Psammechinus miliaris is a sea urchin distributed across the north east Atlantic from Morocco to northern Scandinavia (Mortensen, 1927). In the British Isles, it can occur in dense aggregation

within sheltered locations e.g. Scottish sea lochs, and its distribution frequently coincides with that of *Saccharina latissima* (Kelly, 2000). *Psammechinus miliaris* grazes on a wide array of algae and encrusting organisms, including live *Saccharina latissima* (as in IR.LIR.KVS.SlatPsaVS) (Kelly, 2000; Connor *et al.*, 2004). *Psammechinus miliaris* can reach sexual maturity within the first year, reproduce each successive year, (Elmhirst, 1922) and are reported to live up to 10 years (Allain, 1978). Gametogenesis begins in May and spawning usually occurs between June and August. Depending on food availability, planktonic larvae will then typically settle out within 20-21 days. The gut is fully developed 5-7 days after settlement and juveniles begin grazing (Kelly, 2001).

The red algae *Phyllophora crispa* & *Phyllophora pseudoceranoides* which combined with filamentous green seaweeds characterize the understory community of IR.LIR.KVS.SlatPhyVS. Depending on the level of impact, recovery of the turf may occur through repair and regrowth of damaged fronds, regrowth from crustose bases or via recolonization of rock surfaces where all the plant material is removed. Although there are few case studies following recovery some general trends are apparent. All the red algae (Rhodophyta) exhibit distinct morphological stages over the reproductive life history. This phenomenon is known as heterotrichy or heteromorphy and describes cases where the algal thallus consists of two parts; a prostrate creeping system exhibiting apical growth and functioning as a holdfast. The thalli can regrow from these crusts where they remain supporting recovery of the biotope (Mathieson & Burns, 1975; Dudgeon & Johnson, 1992). The basal crusts are perennial, tough, resistant stages that prevent other species from occupying the rock surface and allow rapid regeneration and where these remain they provide a significant recovery mechanism.

Phyllophora sp. are distributed across the North Atlantic, within Europe specifically are recorded from the Bay of Biscay (Molenaar & Breeman, 1994) up to Trondhiem, Norway (Norwegian Seaweeds, 2015). *Phyllophora* sp. are perennial plants but blades are lost and regrown each year (Newroth, 1972; Molenaar & Breeman, 1994). Culture experiments demonstrated that the time for *Phyllophora pseudoceranoides* to reach sexual maturity was highly temperature dependant, When kept at 10 or 5°C *Phyllophora pseudoceranoides* specimens from Helgoland, Germany and Roscoff, France began sporulation within 3 months. However, there was considerable variation, specimens kept at ≥15°C took ≤30 months to begin sporulation (Molenaar & Breeman, 1994). These observations were conducted within controlled experimental conditions and therefore natural environmental variability is likely to lengthen or possibly shorten the time taken for *Phyllophora* sp. to begin sporulation however it is likely that in a natural setting *Phyllophora pseudoceranoides* would reach maturity within 2 years (High resilience). Please note, Although some general trends are apparent. Recovery rates, for example, will be greatly influenced by whether the crust stages remain from which the thalli can regrow. If a high proportion of bases are lost, then recovery will depend on either vegetative regrowth from remaining bases and or the supply of propagules from neighbouring populations. Dispersal is limited and propagule supply will be influenced by site-specific factors, particularly local water transport, resilience would likely take 2-10 years (Medium resilience).

Resilience assessment. *Saccharina latissima* has potentially rapid recovery rates, recovering from *Strongylocentrotus droebachiensis* 'urchin Barrens' appearing after a few weeks (Leinaas & Christie, 1996), and can reach maturity within 15-20 months (Birkett *et al.*, 1998). *Codium* spp. can produce viable spores within their first year of growth, and annually fragmented sections of thalli can re-attach to hard substrata. *Psammechinus miliaris* can become sexually mature in its first year. Red seaweeds can potentially recover within a single growing season. Resilience is assessed as 'High' where resistance is 'High'. Where resistance is assessed as 'Medium' (loss of <25 % of individuals or cover) and the bases remain then recovery is assessed as 'High'. Where resistance is assessed as

'Low' or 'None', and a high proportion of red seaweed bases are lost then recovery will depend on either vegetative re-growth of red seaweeds from remaining bases and propagule supply from neighbouring populations, Resilience would be assessed as 'Medium'.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	None Q: High A: High C: High	High Q: High A: High C: High	Medium Q: High A: High C: High

Churchill and Moeller (1972) suggested the minimum temperature for the formation of reproductive structures in *Codium fragile* was 12-15°C. Haniask (1979) experimentally measured *Codium fragile* thalli and sporeling growth over a range of environmental conditions. Maximal thalli growth was recorded at 24°C. The upper temperature threshold has been recorded at 30°C and no detectable growth occurs at <6°C.

Mortensen (1927) reported *Psammechinus miliaris* was found in Limfjorden, Denmark where winter water temperatures are regularly just above 0°C (Ursin, 1960). At *Psammichinus miliaris* southern range edge, Morocco and the Azores (Mortensen, 1927), winter-summer temperatures range from 17-21°C (Seatemperature, 2015). The optimal temperature tolerances are therefore likely to be between 0-21°C. Furthermore *Psammichinus miliaris* reproduces in waters around the Faeroes where the summer temperatures seldom exceed 11°C (Ursin, 1960).

The temperature isotherm of 19-20°C has been reported as limiting *Saccharina latissima* geographic distribution (Müller *et al.*, 2009). Gametophytes can develop in ≤23°C (Lüning, 1990) however, the optimal temperature range for sporophyte growth is 10-15°C (Bolton & Lüning, 1982). Bolton & Lüning (1982) experimentally observed that sporophyte growth was inhibited by 50-70% at 20°C and following 7 days at 23°C all specimens completely disintegrated. In the field *Saccharina latissima* has shown significant regional variation in its acclimation to temperature changes, for example Gerard & Dubois (1988) observed sporophytes of *Saccharina latissima* which were regularly exposed to ≥20°C could tolerate these temperatures, whereas sporophytes from other populations which rarely experience ≥17°C showed 100% mortality after 3 weeks of exposure to 20°C. Therefore the response of *Saccharina latissima* to a change in temperatures is likely to be locally variable.

Andersen *et al.* (2011) transplanted *Saccharina latissima* in the Skagerrak region, Norway and from 2006-2009. There was annual variation however high mortality occurred from August-November within each year of the experiment. In 2008 of the original 17 sporophytes 6 survived from March-September (approx. 65% mortality rate). All surviving sporophytes were heavily fouled by epiphytic organisms (estimated cover of 80 & 100%). Between 1960 and 2009, sea surface temperatures in the region have regularly exceeded 20°C and so has the duration which temperatures remain above 20°C. High sea temperatures has been linked to slow growth of *Saccharina latissima* which is likely to decrease the photosynthetic ability of, and increase the vulnerability of *Saccharina latissima* to epiphytic loading, bacterial and viral attacks (Anderson *et al.*, 2011). These factors combined with establishment of annual filamentous algae in Skegerrak, Norway are likely to prevent the establishment of self sustaining populations in the area (Anderson *et al.*, 2011; Moy & Christie, 2012).

Phyllophora crispa and *Phyllophora pseudoceranoides* are sensitive to large changes in temperature. Through culture experiments, 30°C was found lethal to *Phyllophora pseudoceranoides* within 4-12

weeks. At 27°C plants were severely damaged after 3 months but were able to recover when returned to lower temperatures. Furthermore temperature was found to control the time at which *Phyllophora pseudoceranoïdes* begins sporulation. For example, ≥15°C sporulation occurred at 30 months were as 10°C sporulation occurred at 8 months (Molenaar & Breeman, 1994).

IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS & IR.LIR.KVS.SlatPsaVS are distributed throughout the UK (Connor *et al.*, 2004). Northern to southern Sea Surface Temperature (SST) ranges from 8-16°C in summer and 6-13°C in winter (Beszczynska-Möller & Dye, 2013)

Sensitivity assessment. A 2°C increase for one year may impair *Saccharina latissima* sporophyte growth but otherwise not affect the characterizing species. A 5°C increase for one month combined with high UK summer temperatures may cause mortality in *Saccharina latissima* populations that are not acclimated to >20°C. Resistance has been assessed as 'None', to reflect the potential mass mortality effect of sudden temperature increases on *Saccharina latissima*, and resilience as 'Medium'. Sensitivity has been assessed as 'Medium'.

Temperature decrease (local)

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

During winter *Codium spp.* thalli reduce to a small holdfast and biological activity is reduced (Haniask, 1979). Mortensen (1927) reported *Psammechinus miliaris* was found in Limfjorden, Denmark where winter temperatures are regularly just above 0°C. *Saccharina latissima* has a lower temperature threshold for sporophyte growth at 0°C (Lüning, 1990). *Phyllophora pseudoceranoïdes* can tolerate temperatures of -2 and 0°C 3 months (Molenaar & Breeman, 1994). None of the characterizing species are likely to be adversely affected by a temperature decrease at the benchmark level.

Sensitivity assessment. Resistance has been assessed as 'High', resilience as 'High' and sensitivity as 'Not sensitive'.

Salinity increase (local)

None

Q: Low A: NR C: NR

Medium

Q: High A: Medium C: High

Medium

Q: Low A: Low C: Low

Haniask (1979) reported *Codium fragile* salinity tolerances are variable and dependent on temperature. At 24°C thalli growth occurred from 12-42‰, with an optimum from 24-3‰. Gezelius (1962) reported the littoral growth form of *Psammechinus miliaris* had an optimal salinity range of 20-32 ppt, and the sub-littoral growth form had an optimal salinity tolerance of 26-38 ppt.

Karsten (2007) tested the photosynthetic ability of *Saccharina latissima* under acute 2 and 5 day exposure to salinity treatments ranging from 5-60 psu. A control experiment was also carried at 34 psu. *Saccharina latissima* showed high photosynthetic ability at >80% of the control levels between 25-55 psu. The affect of long-term salinity changes (>5 days) or salinity >60 PSU on *Saccharina latissima* photosynthetic ability was not tested. *Phyllophora crispa* and *Phyllophora pseudoceranoïdes* are widely distributed around the UK in full marine conditions (Bunker *et al.*, 2012).

Sensitivity assessment. IR.LIR.KVS.Cod, IR.LIR.KVSSlatPsaVS & IR.LIR.KVS.SlatPhyVS are only recorded from reduced or low salinity conditions (<18-30 psu). An increase to full salinity (30-40‰) may cause declines in *Codium fragile* growth. *Phyllophora* are recorded within full marine salinity, however, may not be sufficiently abundant or out-competed by other red seaweeds to

dominate the habitat in full salinity. Therefore, a long-term change to full salinity (30-40‰) may change the character of the biotope, so that they are replaced by more diverse sheltered rock *Saccharina latissima* biotopes (e.g. IR.LIR.K.Slat). Resistance has been assessed as '**None**', resilience as '**Medium**'. The sensitivity of this biotope to an increase in salinity has been assessed as '**Medium**'.

Salinity decrease (local)	Low	High	Low
	Q: Medium A: High C: High	Q: High A: Medium C: High	Q: Medium A: Medium C: High

Haniask (1979) reported that at 24 °C *Codium fragile* thalli growth could occur from 12-42 ‰, with an optimum from 24-30 ‰. 100% mortality occurred at 6 ‰ and at 12 ‰ growth was reduced. At the extremes of *Codium fragile* temperature tolerance (6 & 30°C) salinity tolerances were restricted, thalli grown at 6°C had a tolerance of 18-36 ‰, and thalli grown at 30 °C had a salinity tolerance of 18-48 ‰ (Haniask, 1979). *Codium fragile* sporlings had narrower salinity and thresholds than mature thalli; Spores did not germinate at < 18 ‰.

Lindahl and Runnström (1929) showed (experimentally) that *Psammechinus miliaris* from the littoral (Z form) and sub-littoral (S form) had different salinity optima. Gezelius (1962) reported the littoral growth form had an optimal salinity range of 20-32 ppt, whereas the sub-littoral growth form 26-38ppt. Mature examples of the littoral growth form tolerated 15 ppt for a period of 27 days, however, were not able to produce gametes at this salinity.

Karsten (2007) tested the photosynthetic ability of *Saccharina latissima* under acute 2 and 5 day exposure to salinity treatments ranging from 5-60 psu. A control experiment was also carried at 34 psu. *Saccharina latissima* showed high photosynthetic ability at >80 % of the control levels between 25-55 psu. Hyposaline treatment of 10-20 psu led to a gradual decline of photosynthetic ability. After 2 days at 5 psu, *Saccharina latissima* showed a significant decline in photosynthetic ability at approx. 30 % of control. After 5 days at 5 psu, *Saccharina latissima* specimens became bleached and showed signs of severe damage. The affect of long-term salinity changes (>5 days) or salinity >60 psu on *Saccharina latissima* photosynthetic ability was not tested. The experiment was conducted on *Saccharina latissima* from the Arctic, and at extremely low water temperatures (1-5 °C) macroalgae acclimation to rapid salinity changes could be slower than at temperate latitudes. It is, therefore, possible that resident *Saccharina latissima* of the UK maybe be able to acclimate to salinity changes more effectively.

Sensitivity assessment. IR.LIR.KVS.Cod is recorded in full salinity but probably exposed to reduced (18-30 ppt) conditions (Connor *et al.*, 2004). A salinity decrease to "Low" (<18 ppt) may cause declines in *Codium spp.* growth and detriment the biotope. As a result, the *Codium* abundance could fall resulting in the SlatPhyVS biotope. IR.LIR.KVS.SlatPsaVS and IR.LIR.KVS.SlatPhyVS are recorded in 'reduced' and 'low' salinity, A further reduction in salinity would result in close to freshwater conditions and, however unlikely, would result in loss of the biotopes. Resistance has been assessed as '**Low**' and resilience as '**High**'. Therefore, the sensitivity of this biotope to a decrease in salinity has been assessed as '**High**'.

Water flow (tidal current) changes (local)	High	High	Not sensitive
	Q: Low A: NR C: NR	Q: Medium A: High C: High	Q: Low A: Low C: Low

Information concerning the effects of increasing water flow on *Codium spp.* or *Psammechinus miliaris* is limited. IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS & IR.LIR.KVS.SlatPsaVS are

predominantly recorded from sites with very weak to weak tidal streams (Connor *et al.*, 2004).

Peteiro & Freire (2013) measured *Saccharina latissima* growth from 2 sites, the first had maximal water velocities of 0.3 m/sec and the second 0.1 m/sec. At site 1 *Saccharina latissima* had significantly larger biomass than at site 2 (16 kg/m to 12 kg/m respectively). Peteiro & Freire (2013) suggested that faster water velocities were beneficial to *Saccharina latissima* growth. However, Gerard & Mann (1979) found *Saccharina latissima* productivity is reduced in moderately strong tidal streams (≤ 1 m/sec) when compared to weak tidal streams (< 0.5 m/sec). Despite the results published in Gerard & Mann (1979) *Saccharina latissima* can characterize or be a dominant in the tide swept biotopes IR.MIR.KT.XKTX & IR.MIR.KT.SlatT, which have been recorded from very strong (> 3 m/sec) to moderately strong tidal streams (≤ 1 m/sec) (Connor *et al.*, 2004), indicating *Saccharina latissima* can tolerate greater tidal streams than < 1 m/sec.

Sensitivity assessment. IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS & IR.LIR.KVS.SlatPsaVS are classed as low energy biotopes, restricted to only weak tidal streams. Many of the characteristic species are found in a range of tidal regimes so that a change in flow velocities of between 0.1-0.2 m/sec would not cause a significant effect on most species present. In SlatCod an increase in water flow at the benchmark may be enough to remove the silt that characterizes the biotope, and allow the abundance of *Saccharina latissima* to increase. In SlatPsa, an increase in water flow to moderately strong or strong would probably reduce the abundance of *Echinus esculentus* and to a lesser extent *Psammechinus miliaris* and favour a change from SlatPsaVS to SlatPhyVS. However, at the benchmark level, there is only likely to be slight changes in the character of the biotope and the KVS complex would remain.

Resistance has been assessed as '**Medium**', resilience as '**High**'. Sensitivity has been assessed as '**Low**' at the benchmark level.

Emergence regime changes

Low

Q: Low A: NR C: NR

Medium

Q: High A: Low C: High

Medium

Q: Low A: NR C: NR

IR.LIR.KVS.Cod, IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS & IR.LIR.KVS.SlatPsaVS are predominantly shallow biotopes recorded from 0-10 m BCD. An increase in emergence will result in an increased risk of desiccation and mortality of the macro-algae of the biotope. Removal of canopy forming kelps, through desiccation, has also been shown to increase desiccation and mortality of the understory macro-algae (Hawkins & Harkin, 1985). Thomsen & McGlathery (2007) demonstrated that *Codium fragile* biomass declined if artificially placed at higher tidal elevations, and would therefore likely be sensitive to changes in emergence regime. Many of the dominant species also occur in the lower intertidal, however, the biotope would probably be replaced by a lower shore equivalent. Providing that suitable substrata are present, the biotope is likely to re-establish further down the shore within a similar emergence regime to that which existed previously.

Sensitivity assessment. Resilience has been assessed as '**Low**'. Resistance as '**Medium**'. The sensitivity of this biotope to a change in emergence is considered as '**Medium**'.

Wave exposure changes (local)

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS & IR.LIR.KVS.SlatPsaVS are classed as low energy biotopes, recorded from sheltered-ultra wave sheltered sites (Connor *et al.*, 2004). Therefore, a large scale

increase in wave exposure is likely to have a fundamental effect on the characterizing species. However, evidence that specifically relates to the tolerance of the characterizing species to increases in wave exposure is limited.

Bulleri & Airoidi (2005) recorded the seasonal abundance of *Codium fragile* on the wave exposed and sheltered faces of breakwaters (coastal defence structures) built in the Adriatic sea. *Codium fragile* density was similar across both the exposed and sheltered sides in spring-early summer, however as summer progressed *Codium fragile* density declined on the exposed side of the breakwater. *Codium fragile* thalli also attained greater sizes (>14 cm) were more branched and had higher biomass on the sheltered faces of the breakwater. Indicating, that wave exposure has an impact on the density of *Codium spp.* thalli.

Little evidence on the effect of wave exposure on *Psammechinus miliaris* or *Saccharina latissima* was found, other than they are predominantly recorded in wave sheltered locations (Birkett *et al.*, 1998; Kelly, 2000).

Sensitivity assessment. Wave exposure is one of the principal defining features of rock biotopes, and large changes in wave exposure are likely to alter the relative abundance of the dominant macro-algae, grazing and understory community, and hence, the biotope. However, a change in near shore significant wave height of 3-5% is unlikely to have any significant effect on IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS or IR.LIR.KVS.SlatPsaVS. Resistance has been assessed as 'High', resilience as 'High' and sensitivity as 'Not Sensitive' at the benchmark level.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes. The effects of copper, zinc and mercury on *Saccharina latissima* have been investigated by Thompson and Burrows (1984). They observed that the growth of sporophytes was significantly inhibited at 50 µg Cu /l, 1000 µg Zn/l and 50 µg Hg/l. Zoospores were found to be more intolerant and significant reductions in survival rates were observed at 25 µg Cu/l, 1000 µg Zn/l and 5 µg/l.

At the time of writing, little is known about the effects of heavy metals on echinoderms. Bryan (1984) reported that early work had shown that echinoderm larvae were intolerant of heavy metals, e.g. the intolerance of larvae of *Paracentrotus lividus* to copper (Cu) had been used to develop a water quality assessment. Kinne (1984) reported developmental disturbances in *Echinus esculentus* exposed to waters containing 25 µg / l of copper (Cu). Sea-urchins, especially the eggs and larvae, are used for toxicity testing and environmental monitoring (reviewed by Dinnel *et al.* 1988). Taken together with the findings of Gommez & Miguez-Rodriguez (1999) above it is likely that echinoderms are intolerant of heavy metal contamination.

Hydrocarbon & PAH contamination

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Saccharina latissima fronds, being predominantly subtidal, would not come into contact with freshly released oil but only to sinking emulsified oil and oil adsorbed onto particles (Birkett *et al.*, 1998). The mucilaginous slime layer coating of laminariales may protect them from smothering by oil. Hydrocarbons in solution reduce photosynthesis and may be algicidal. However, Holt *et al.* (1995) reported that oil spills in the USA and from the 'Torrey Canyon' had little effect on kelp forests. Similarly, surveys of subtidal communities at a number sites between 1-22.5 m below chart datum showed no noticeable impacts of the *Sea Empress* oil spill and clean up (Rostron & Bunker, 1997). An assessment of holdfast fauna in *Laminaria* showed that although species richness and diversity decreased with increasing proximity to the *Sea Empress* oil spill, overall the holdfasts contained a reasonably rich and diverse fauna, even though oil was present in most samples (Somerfield & Warwick, 1999).

Echinoderms seem especially sensitive to the toxic effects of oil, likely because of the large amount of exposed epidermis (Suchanek, 1993). Schäfer & Köhler (2009) found 20 day exposure to sub-lethal concentrations of phenanthrene resulted in severe ovarian lesions of *Psammechinus miliaris* limiting the production of gametes.

Following the *Torrey Canyon* incident, large numbers of dead *Psammechinus miliaris* were found in the vicinity of Sennen, UK possibly due to exposure to the oil spill and the heavy spraying of hydrocarbon based dispersants in that area (Smith, 1968). Other significant effects have been observed in other species of urchins. For example, mass mortality of the echinoderm *Echinocardium cordatum* was observed shortly after the *Amoco Cadiz* oil spill (Cabioch *et al.*, 1978) and reduced abundance of the species was detectable up to >1000 m away one year after the discharge of oil-contaminated drill cuttings in the North Sea (Daan & Mulder, 1996). In the Mediterranean around Naples, urchins were absent from areas which had visible signs of massive pollution of both sewage and oil. *Echinus esculentus* populations in the vicinity of an oil terminal in A Coruna Bay, Spain, showed developmental abnormalities in the skeleton. The tissues contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu) (Gomez & Miguez-Rodriguez, 1999). But the observed effects may have been due to a single contaminant or synergistic effects of all present.

Cullinane *et al.* (1975) found large quantities of *Codium fragile* washed up on Relane, Bantry Bay, USA shortly after a large oil spill. No other evidence could be located for the effect of hydrocarbon & PAH contamination on *Codium* spp.

Synthetic compound contamination

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Johansson (2009) exposed samples of *Saccharina latissima* to several antifouling compounds, observing chlorothalonil, DCOIT, dichlofluanid and tolylfluanid inhibited photosynthesis. Exposure to Chlorothalonil and tolylfluanid, was also found to continue inhibiting oxygen evolution after exposure had finished, and may cause irreversible damage. Smith (1968) noted that epiphytic and

benthic red algae were intolerant of dispersant or oil contamination due to the *Torrey Canyon* oil spill; only the epiphytes *Cryptopleura ramosa* and *Spermothamnion repens* and some tufts of *Jania rubens* survived together with *Osmundea pinnatifida*, *Gigartina pistillata* and *Phyllophora crispa* from the sublittoral fringe. Considerable observations and work, mainly on *Echinus esculentus* but also on *Psammechinus miliaris* (Smith, 1968; Gomme & Miguez-Rodriguez, 1999; Dinnel *et al.*, 1988) indicate high intolerance to synthetic contaminants. Newton & McKenzie (1995) state that echinoderms tend to be very intolerant of various types of marine pollution, but there is little more detailed information than this. Following the *Torrey Canyon* incident, large numbers of dead *Psammechinus miliaris* in the vicinity of Sennen, UK presumably due to the heavy spraying of dispersants in that area and exposure to the oil spill (Smith, 1968).

Radionuclide contamination

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

No evidence.

Introduction of other substances

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation

High

Q: Medium A: High C: High

High

Q: Medium A: High C: High

Not sensitive

Q: Medium A: High C: High

Reduced oxygen concentrations can inhibit both photosynthesis and respiration in macroalgae (Kinne, 1977). Despite this, macroalgae are thought to buffer the environmental conditions of low oxygen, thereby acting as a refuge for organisms in oxygen depleted regions especially if the oxygen depletion is short-term (Frieder *et al.*, 2012). A rapid recovery from a state of low oxygen is expected if the environmental conditions are transient. If levels do drop below 4 mg/l negative effects on these organisms can be expected, with adverse effects occurring below 2mg/l (Cole *et al.*, 1999).

Under hypoxic conditions, echinoderms become less mobile and stop feeding. The death of a bloom of the phytoplankton *Gyrodinium aureolum* in Mounts Bay, Penzance in 1978 produced a layer of brown slime on the sea bottom. This resulted in the death of fish and invertebrates, including *Echinus esculentus*, presumably due to anoxia caused by the decay of the dead dinoflagellates (Griffiths *et al.*, 1979). Spicer (1995) investigated the effects of environmental hypoxia on the oxygen and acid-base status of *Psammechinus miliaris*. Oxygen uptake is not regulated by this species during progressive hypoxia. The habitat of this species includes rock pools on the shore that can experience quite severe hypoxia or even anoxia. *Psammechinus miliaris* must be able to tolerate low oxygen conditions provided the event is brief. In prolonged events, subtidal *Psammechinus miliaris* would presumably react in a similar fashion to the *Echinus esculentus* above.

Sensitivity Assessment. Reduced oxygen levels are likely to inhibit photosynthesis and respiration but not cause a loss of the macroalgae population directly. long-term de-oxygenation could, however, cause mortality in echinoderms; however intertidal populations of *Psammechinus miliaris* are likely to be tolerant of hypoxia conditions. Resistance has been assessed as 'Medium',

Resilience as '**High**'. Sensitivity has been assessed as '**Low**'.

Nutrient enrichment

Medium

Q: High A: High C: High

High

Q: High A: High C: High

Low

Q: High A: High C: High

Johnston & Roberts (2009) conducted a meta-analysis, which reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected 6 marine habitats (including subtidal reefs). A 30-50% reduction in species diversity and richness was identified from all habitats exposed to the contaminant types. Johnston & Roberts (2009) also highlighted that macroalgal communities are relatively tolerant to contamination, but that contaminated communities can have low diversity assemblages which are dominated by opportunistic and fast growing species (Johnston & Roberts, 2009 and references therein).

Conolly & Drew (1985) found *Saccharina latissima* sporophytes had relatively higher growth rates when in close proximity to a sewage outlet in St Andrews, UK when compared to other sites along the east coast of Scotland. At St Andrews, nitrate levels were 20.22 μM , which represents an approx 25 % increase when compared to other comparable sites (approx 15.87 μM). Handå *et al.* (2013) also reported *Saccharina latissima* sporophytes grew approx 1 % faster per day when in close proximity to Norwegian Salmon farms, where elevated ammonium can be readily absorbed. Read *et al.* (1983) reported after the installation of a new sewage treatment works which reduced the suspended solid content of liquid effluent by 60% in the Firth of Forth, *Saccharina latissima* became abundant where previously it had been absent.

Haniask (1979) observed that *Codium fragile* growth rate increased when exposed to elevated nitrogen (Nitrate, Nitrite, Ammonium and Urea). After 21 day nitrogen enrichment treatments *Codium fragile* grew on average 23-25 mm, whereas in the no enrichment treatment *Codium fragile* grew 4.8 mm. Conversely Thomsen & McGlathery (2006) observed that short-term nutrient enrichment did not increase the biomass of *Codium fragile*, however, the authors suggested that *Codium* spp. store excess Nitrogen to sustain growth if nutrients become depleted. Despite disagreement between the authors on the effect of enrichment, in both examples, enrichment did not have a detectable negative impact on *Codium* spp.

Sensitivity assessment. The evidence suggests that enrichment would not negatively impact on *Codium* spp. growth or directly affect *Saccharina latissima*. However indirectly nutrient enrichment may increase turbidity which may decrease water clarity and, therefore, macro-algae photosynthesis. Resistance has therefore been assessed as '**Medium**', resilience as '**High**'. Sensitivity has been assessed as '**Low**'.

Organic enrichment

Medium

Q: High A: High C: High

High

Q: High A: High C: High

Low

Q: High A: High C: High

Johnston & Roberts (2009) conducted a meta-analysis, which reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected 6 marine habitats (including subtidal reefs). A 30-50% reduction in species diversity and richness was identified from all habitats exposed to the contaminant types. Johnston & Roberts (2009) however also highlighted that macroalgal communities are relatively tolerant to contamination, but that contaminated communities can have low diversity assemblages which are dominated by opportunistic and fast growing species (Johnston & Roberts, 2009 and references therein).

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Sensitivity assessment. The evidence suggests that enrichment would not negatively impact on *Codium* spp. growth or directly affect *Saccharina latissima*. However, indirect organic enrichment may increase turbidity, which may decrease water clarity and therefore negatively affect macro-algae photosynthesis and growth. Resistance has therefore been assessed as '**Medium**', resilience as '**High**'. Sensitivity has been assessed as '**Low**'.

A Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

All marine habitats and benthic species are considered to have a resistance of '**None**' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is '**Very Low**'). Sensitivity within the direct spatial footprint of this pressure is, therefore, '**High**'. Although no specific evidence is described confidence in this assessment is '**High**', due to the incontrovertible nature of this pressure.

Physical change (to another seabed type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High
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This biotope forms on hard rock substrata, i.e. bedrock, boulders and cobbles. A change from hard rock to sedimentary substrata would result in permanent loss of the biotope. Therefore, resistance is assessed as **None**, resilience as **Very low** and sensitivity as **High**. Confidence is assessed as High due to the incontrovertible nature of the pressure.

Physical change (to another sediment type)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR
--	--	--	--

Not relevant on hard rock substrata.

Habitat structure changes - removal of substratum (extraction)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR
--	--	--	--

Not relevant on hard rock substrata.

Abrasion/disturbance of the surface of the substratum or seabed**None**

Q: Low A: NR C: NR

High

Q: Medium A: High C: High

Medium

Q: Low A: Low C: Low

Abrasion of the substratum e.g. from bottom or pot fishing gear, cable laying etc. may cause localised mobility of the substrata and mortality of the resident community. The effect would be situation dependent however if bottom fishing gear were towed over a site it may mobilise a high proportion of the rock substrata and cause high mortality in the resident community. **Sensitivity assessment.** Resistance has been assessed as '**None**', Resilience as '**High**'. Sensitivity has been assessed as '**Medium**'.

Penetration or disturbance of the substratum subsurface**Not relevant (NR)**

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Penetration is unlikely to be relevant to hard rock substrata. Therefore, the pressure is **Not relevant**. However, physical disturbance of the surface is assessed under 'abrasion' above.

Changes in suspended solids (water clarity)**Medium**

Q: Medium A: High C: High

High

Q: High A: Medium C: High

Low

Q: Medium A: Medium C: High

Suspended Particle Matter (SPM) concentration has a negative linear relationship with sub-surface light attenuation (K_d) (Devlin *et al.*, 2008). An increase in SPM results in a decrease in sub-surface light attenuation. Light availability and water turbidity are principal factors in determining depth range at which kelp can be found (Birkett *et al.*, 1998). Light penetration influences the maximum depth at which kelp species can grow and it has been reported that laminarians grow at depths at which the light levels are reduced to 1 percent of incident light at the surface. Maximal depth distribution of laminarians, therefore, varies from 100 m in the Mediterranean to only 6-7 m in the silt laden German Bight. In Atlantic European waters, the depth limit is typically 35 m. In very turbid waters the depth at which kelp is found may be reduced, or in some cases excluded completely (e.g. Severn Estuary), because of the alteration in light attenuation by suspended sediment (Lüning, 1990; Birkett *et al.*, 1998).

Laminaria spp. show a decrease of 50 % photosynthetic activity when turbidity increases by 0.1/m (light attenuation coefficient = 0.1-0.2/m; Staehr & Wernberg, 2009). An increase in water turbidity will likely decrease the photosynthetic ability of, abundance and density of *Saccharina latissima*. *Codium fragile* is photosynthetically efficient at low light levels (Ramus *et al.*, 1976). Thomsen & McGlathery (2006) also demonstrated that *Codium fragile* gained biomass in both low and high light conditions, and found no apparent negative effect of shading on *Codium fragile* biomass. *Psammechinus miliaris* is omnivorous, feeding directly on live and dead algae but also on an array attached fauna (Kelly, 2000). The feeding plasticity of *Psammechinus miliaris* is likely to ameliorate some of the effects of diminished kelp growth as a result of decreased light availability, however, a decrease in *Saccharina latissima* may cause some declines in *Psammechinus miliaris* abundance.

Many red algal species are scour tolerant, and occur in turbid waters and in general algal turfs replace fucoids and kelps in areas where turbidity and sedimentation increase (Airoldi, 2003). Furthermore, many red algal species occur beneath canopies of larger macroalgae (e.g.

IR.HIR.KFaR.LhyPR) and are tolerant of low light levels (Gantt, 1990).

Sensitivity Assessment. A decrease in turbidity is likely to support enhanced growth (and possible habitat expansion) and is therefore not considered in this assessment. However, an increase in turbidity is likely to result in the loss of *Saccharina latissima* at the deeper extent of the biotope. *Codium spp.*, *Psammechinus miliaris* and red algal species are resistant to decreases in water clarity. To represent the potential decline in *Saccharina latissima* resistance to this pressure has been defined as 'Medium' and resilience to this pressure is defined as 'High' at the benchmark level due to the scale of the impact. Hence, this biotope is regarded as having a sensitivity of 'Low'.

Smothering and siltation rate changes (light)

None

Q: Medium A: Medium C: High

High

Q: High A: Medium C: Medium

Medium

Q: Medium A: Medium C: Medium

Smothering by sediment e.g. 5 cm material during a discrete event, is unlikely to damage *Saccharina latissima* sporophytes but may affect holdfast fauna, gametophyte survival, interfere with zoospore settlement and, therefore, recruitment processes (Moy & Christie, 2012). Given the short life expectancy of *Saccharina latissima* (2-4 years-(Parke, 1948)), IR.LIR.KVS.SlatPhyVS is likely to be dependent on annual *Saccharina latissima* recruitment (Moy & Christie, 2012). Given the microscopic size of the gametophyte, 5 cm of sediment could be expected to significantly inhibit growth. However, laboratory studies showed that kelp gametophytes can survive in darkness for between 6-16 months at 8°C and would probably survive smothering by a discrete event. Once returned to normal conditions the gametophytes resumed growth or maturation within 1 month (Dieck, 1993). Intolerance to this factor is likely to be higher during the peak periods of sporulation and/or spore settlement.

Mature *Codium tomentosum* thalli can grow up to 30 cm long (Pizzolla, 2007). Therefore, during summer when thalli are erect light deposition of sediment is unlikely to inundate thalli, however if sediment is deposited during winter when the thalli are fragmented and reduced to the holdfast (Haniask, 1979) then *Codium spp.* thalli will become inundated. It is unknown whether retained sediment would inhibit growth if the holdfast was inundated the following spring. *Psammechinus miliaris* is quite small (typically up to 4 cm) and is likely to be inundated by 5 cm of sediment (Jackson, 2008). If unable to 'dig out' of the sediment, deposited sediment may cause mortality.

The effect of deposition of 5 cm sediment *Phyllophora crispa* and *Phyllophora pseudoceranoides* is likely to be seasonally variable. As highlighted within the resilience section, *Phyllophora sp.* can lose fronds during winter. *Phyllophora crispa* fronds can grow to a length of 15cm and *Phyllophora pseudoceranoides* can grow to a length of 10cm (Bunker *et al.*, 2012). Therefore, if plants are complete deposition is not likely to completely inundate mature individuals. However if sediment deposition occurs during periods of early seasonal thalli growth then this could affect *Phyllophora sp.* growth.

IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS and IR.LIR.KVS.SlatPsaVS are classed as low energy habitats, and are therefore unlikely to experience >moderate tidal streams (>0.5 m/sec) or wave action.

Sediment could, therefore, remain within the host habitat and recovery rate would be related to sediment retention but will probably be dissipated within a year. Deposited sediments could affect kelp recruitment (Birkett *et al.*, 1998) and the survival of *Psammechinus miliaris*.

Sensitivity assessment. SlatCod is a heavily silted biotope (Connor *et al.*, 2004) so an addition of 5

cm of fines may not have a significant effect on the biotope. In SlatPsaVS and SlatPhyV deposited fine sediment may remain for some time (depending on local conditions) and result in the smothering of small invertebrates, and smothering of short turf forming red algae and encrusting corallines. Smothering would inhibit photosynthesis, growth for algae, and possibly lead to mortality of germlings. To reflect the potential effect that deposited sediment could have on *Psammechinus miliaris*. Resistance has been assessed as '**None**', and resilience as '**High**'. Therefore, sensitivity has been assessed as '**Medium**'.

Smothering and siltation rate changes (heavy)

None

Q: Medium A: Medium C: Medium

Medium

Q: High A: High C: High

Medium

Q: Medium A: Medium C: High

Smothering by sediment e.g. 30 cm material during a discrete event, is unlikely to damage *Saccharina latissima* sporophytes but may affect holdfast fauna, gametophyte survival, interfere with zoospore settlement and, therefore, recruitment processes (Moy & Christie, 2012). Given the short life expectancy of *Saccharina latissima* (2-4 years (Parke, 1948)), IR.LIR.KVS.SlatPhyVS is likely to be dependent on annual *Saccharina latissima* recruitment (Moy & Christie, 2012). Given the microscopic size of the gametophyte, 30cm of sediment could be expected to significantly inhibit growth. However, laboratory studies showed that kelp gametophytes can survive in darkness for between 6-16 months at 8°C and would probably survive smothering by a discrete event. Once returned to normal conditions the gametophytes resumed growth or maturation within 1 month (Dieck, 1993). Intolerance to this factor is likely to be higher during the peak periods of sporulation and/or spore settlement.

Mature *Codium tomentosum* thalli can grow up to 30 cm long (MarLIN, 2015). Hence, 30 cm of deposited sediment is likely to inundate mature thalli. During winter, thalli fragment and individuals are reduced to a holdfast. It is unknown whether retained sediment would inhibit growth if the holdfast was inundated the following spring. *Psammechinus miliaris* is quite small (typically up to 40 mm) and is likely to be inundated by 30 cm of sediment (Jackson, 2008). If unable to 'dig out' of the sediment, deposited sediment may cause mortality. *Phyllophora crispa* fronds can grow to a length of 15 cm and *Phyllophora pseudoceranoides* can grow to a length of 10cm (Bunker *et al.*, 2012). Deposition of 30 cm sediment is likely to completely inundate *Phyllophora crispa* and *Phyllophora pseudoceranoides*.

IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS and IR.LIR.KVS.SlatPsaVS are classed as low energy habitats, and are therefore unlikely to experience >moderate tidal streams (>0.5 m/sec) or wave action. Sediment could, therefore, remain within the host habitat and recovery rate would be related to sediment retention but will probably be dissipated within a year. Deposited sediments could affect macroalgae recruitment (Birkett *et al.*, 1998) and the survival of *Psammechinus miliaris*.

Sensitivity assessment Deposition of 30 cm of sediment is likely to inundate all but large macroalgae, e.g. mature *Saccharina latissima*, and cause mortality in *Codium spp.* and understory red seaweeds. As the deposit may remain for some time (depending on local conditions) and mortality is likely. Resistance has been assessed as of '**None**'; resilience has been assessed as '**Medium**'. Sensitivity has been assessed as '**Medium**'.

Litter

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed.

Electromagnetic changes	No evidence (NEv)	Not relevant (NR)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

No evidence.

Underwater noise changes	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

No evidence.

Introduction of light or shading	Low	Medium	Medium
	Q: Low A: NR C: NR	Q: Low A: NR C: NR	Q: Low A: NR C: NR

There is no evidence to suggest that anthropogenic light sources would affect macro-algae. Shading (e.g. by the construction of a pontoon, pier etc) could adversely affect IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS and IR.LIR.KVS.SlatPsaVS in areas where the water clarity is also low, and tip the balance to shade tolerant species, resulting in the loss of the biotope directly within the shaded area, or a reduction in seaweed abundance.

Sensitivity assessment. Resistance is probably 'Low', with a 'Medium' resilience and a sensitivity of 'Medium', albeit with 'low' confidence due to the lack of direct evidence.

Barrier to species movement	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Not relevant. This pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit the dispersal of spores. But spore dispersal is not considered under the pressure definition and benchmark.

Death or injury by collision	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Not relevant. Collision from grounding vessels is addressed under abrasion above.

Visual disturbance	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Not relevant.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	No evidence (NEv)	No evidence (NEv)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Saccharina latissima has shown significant regional acclimation to environmental conditions. Gerard & Dubois (1988) found *Saccharina latissima* sporophytes which were regularly exposed to $\geq 20^{\circ}\text{C}$ could tolerate these high temperatures whereas sporophytes from other populations which rarely experience $\geq 17^{\circ}\text{C}$ showed 100 % mortality after 3 weeks of exposure to 20°C . It is, therefore, possible that transplanted eco-types of *Saccharina latissima* may react differently to environmental conditions that differ from those of their origin.

However, there was little evidence for translocation of any other characteristic species over significant geographic distances. Nor was there any evidence regarding the genetic modification or effects of translocation.

Introduction or spread of invasive non-indigenous species

Low

Q: Medium A: High C: High

Very Low

Q: Medium A: High C: High

High

Q: Medium A: High C: High

Codium fragile subsp. tomentosoides is a native green alga of Japan which at the time of writing has spread throughout Europe, The Americas, South Africa, Australia and New Zealand. During kelp canopy clearance experiments in Nova Scotia, it was observed that following removal of *Laminaria longicuris* canopies *Codium fragile subsp. tomentosoides* can opportunistically colonize cleared patches and inhibit kelp re-colonization (Provan *et al.*, 2005).

Undaria pinnatifida has received a large amount of research attention as a major Invasive Non-Indigenous Species (INIS) which could out-compete native UK kelp habitats (see Farrell & Fletcher, 2006; Thompson & Schiel, 2012, Brodie *et al.*, 2014; Heiser *et al.*, 2014). *Undaria pinnatifida* was first recorded in the UK, Hamble Estuary, in June 1994 (Fletcher & Manfredi, 1995) and has since spread to a number of British ports. *Undaria pinnatifida* is an annual species, sporophytes appear in Autumn and grow rapidly throughout winter and spring during which they can reach a length of 1.65 m (Birkett *et al.*, 1998). Farrell & Fletcher (2006) suggested that native short lived species that occupy similar ecological niches to *Undaria pinnatifida*, such as *Saccharina latissima*, are likely to be worst affected and out-competed by *Undaria pinnatifida*. Where present an abundance of *Undaria pinnatifida* has corresponded to a decline in *Saccharina latissima* (Farrell & Fletcher, 2006) and *Laminaria hyperborea* (Heiser *et al.*, 2014).

In New Zealand, Thompson and Schiel (2012) observed that native fucoids could out-compete *Undaria pinnatifida* and re-dominate the substratum. However, Thompson and Schiel (2012) suggested the fucoid recovery was partially due to an annual *Undaria pinnatifida* die back, which as noted by Heiser *et al.*, (2014) does not occur in Plymouth Sound, UK. *Undaria pinnatifida* was successfully eradicated on a sunken ship in Clatham Islands, New Zealand, by applying a heat treatment of 70°C (Wotton *et al.*, 2004) however numerous other eradication attempts have failed, and as noted by Fletcher & Farrell, (1999) once established *Undaria pinnatifida* resists most attempts at long term removal. The biotope is unlikely to fully recover until *Undaria pinnatifida* is fully removed from the habitat, which as stated above is unlikely to occur.

Sensitivity assessment. Resistance to the pressure is considered '**Low**', and resilience '**Very Low**'. The sensitivity of this biotope to the introduction of microbial pathogens is assessed as '**High**'.

Introduction of microbial pathogens

Medium

Q: Medium A: High C: Medium

High

Q: Low A: NR C: NR

Low

Q: Medium A: NR C: NR

Saccharina latissima may be infected by the microscopic brown alga *Streblonema aecidioides*. Infected algae show symptoms of Streblonema disease, i.e. alterations of the blade and stipe ranging from dark spots to heavy deformations and completely crippled thalli (Peters & Scaffelke, 1996). Infection can reduce growth rates of host algae.

Psammechinus miliaris is susceptible to 'Bald-sea-urchin disease', which causes lesions, loss of spines, tube feet, pedicellariae, destruction of the upper layer of skeletal tissue and death (Maes *et al.*, 1986). It is thought to be caused by the bacteria *Vibrio anguillarum* and *Aeromonas salmonicida*. This disease has been recorded from *Psammechinus miliaris* from the French Atlantic coast. Although associated with mass mortalities of *Strongylocentrotus franciscanus* in California and *Paracentrotus lividus* in the French Mediterranean there is no evidence of mass mortalities of *Psammechinus miliaris* associated with this disease around Britain and Ireland.

Sensitivity assessment. Resistance to the pressure is considered '**Medium**', and resilience '**High**'. The sensitivity of this biotope to the introduction of microbial pathogens is assessed as '**Low**'.

Removal of target species

Not relevant (NR)

Q: High A: High C: High

Not relevant (NR)

Q: High A: High C: High

Not relevant (NR)

Q: High A: High C: High

Targeted removal of characterizing species IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS & IR.LIR.KVS.SlatPsaVS would likely have a fundamental effect on the character of the biotopes. *Saccharina latissima* is commercially cultivated, however typically sporophytes are matured on ropes (Handå *et al.*, 2013) and not directly extracted from the seabed, as is the case with *Laminaria hyperborea* (see Christie *et al.*, 1998). As a consequence related literature on which to assess the "resistance" of *Saccharina latissima* to targeted harvesting is sparse. Similarly at the time of writing, no evidence could be found to suggest that *Codium spp.* was extracted for commercial or recreational purposes. *Psammechinus miliaris* is targeted as a potential aquaculture species. When fed a nutritious diet in culture, the gonad biomass rapidly proliferates which can then be marketed as urchin "roe" (Kelly *et al.*, 1998; 2000). However, Kelly (2000) concluded that there was no viability in a *Psammechinus miliaris* commercial fishery because of the low gonad content of wild populations. While some extraction of *Psammechinus miliaris* may conceivably develop for roe-enhancement through feeding artificial or nutrient enriched diets (Dr Maeve Kelly pers comm. From Kelly, 2000), this is currently not in practice within the UK.

Sensitivity assessment. None of the characterizing species are commercially extracted from the seabed. If extracted in the future resistance would need to be re-assessed. This pressure has been assessed as '**Not Relevant**'.

Removal of non-target species

Low

Q: Low A: NR C: NR

High

Q: High A: High C: High

Low

Q: Low A: Low C: Low

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of non-target species on this biotope. Incidental removal of the key characterizing species and associated species would alter the character of the biotope. IR.LIR.KVS.Cod, IR.LIR.KVS.SlatPhyVS and IR.LIR.KVS.SlatPsaVS are characterized by a canopy of *Saccharina latissima*. *Saccharina latissima* provides a canopy under which a variety of red seaweeds grow, including, *Phyllophora sp.* (as in IR.LIR.KVS.SlatPhyVS). The loss of the canopy due to incidental removal as by-catch would, therefore, alter the character of the habitat and result in the

loss of species richness. The ecological services such as primary and secondary production provided by these species would also be lost. *Codium spp.* is also a key/characterizing species that may be removed through incidental/accidental by-catch. Removal *Codium spp.* would by definition also change biotope structure

Psammechinus miliaris may suffer as a result of trawling or dredging for other benthic species. Species with fragile tests such as urchins have been reported to be particularly sensitive to damage from mobile fishing gear (see Jennings & Kaiser, 1998; Bergman & van Santbrink, 2000). Kaiser & Spencer (1994) reported a ca 20 – 50% mortality in *Psammechinus miliaris* as a result of a single pass of an experimental 4 m beam trawl.

Sensitivity assessment. For this assessment, it has been assumed that incidental removal would result in complete removal of the characterizing species. Resistance has been assessed as **Low**, resilience as **'High'** and sensitivity as **'Low'**.

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